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A RETURN LOOK AT DORMANT SEASON IRRIGATION STRATEGIES

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ABSTRACT

Many of the irrigation systems today in the Central Great Plains no longer have the capacity to apply peak irrigation needs during the summer and must rely on soil water reserves to buffer the crop from water stress. Considerable research was conducted on preseason irrigation in the US Great Plains region during the 1980s and 1990s. In general, the conclusions were that in-season irrigation was more beneficial than preseason irrigation and that often preseason irrigation was not warranted. The objective of this study was to determine whether preseason irrigation would be profitable with today's lower capacity wells. A field study was conducted at the KSU-SWREC near Tribune, Kansas, from 2006 to 2009. The study was a factorial design of preplant irrigation (0 and 3 in), well capacities (0.1, 0.15, and 0.20 in day^{-1} capacity), and seeding rate (22,500, 27,500, and 32,500 seeds a^{-1}). Preseason irrigation increased grain yields an average of 16 bu a^{-1}. Grain yields were 29% greater when well capacity was increased from 0.10 to 0.20 in day^{-1}. Crop water productivity (CWP, grain yield divided by crop water use) was not significantly affected by well capacity or preseason irrigation. Preseason irrigation was profitable at all well capacities. At well capacities of 0.10 and 0.15 in day^{-1}, a seeding rate of 27,500 seeds a^{-1} was generally more profitable than lower or higher seeding rates. A higher seeding rate (32,500 seeds a^{-1}) increased profitability when well capacity was increased to 0.2 in day^{-1}.

INTRODUCTION

Irrigated crop production is a mainstay of agriculture in western Kansas. However, with declining water levels in the Ogallala aquifer and increasing energy costs, optimal utilization of limited irrigation water is required. The most common crop grown under irrigation in western Kansas is corn (about 50% of the irrigated acres). Almost all of the groundwater pumped from the High Plains (Ogallala) Aquifer is used for irrigation (97% of the groundwater pumped in western Kansas in 1995 [Kansas Department of Agriculture, 1997]). In 1995, of 3 billion m^3 of water pumped for irrigation in western Kansas, 1.41 million acre-ft (57%) were applied to corn (Kansas Water Office, 1997). This amount of water withdrawal from the aquifer has reduced saturated thickness (up to 150 ft in some areas) and well capacities.

Considerable research was conducted on preseason irrigation in the US Great Plains region during the 1980s and 1990s (Stone et al., 1983, 1987, and 1994; Lamm and Rogers, 1985; Musick and Lamm, 1990; Rogers and Lamm, 1994). In general, the conclusions were that in-season irrigation was more beneficial than preseason irrigation and that often preseason irrigation was not warranted because overwinter precipitation could replenish a significant portion of the soil water profile. Lamm and Rogers (1985) developed a relationship between fall ASW and over-winter precipitation on spring ASW (Fig. 1). In a review of preplant irrigation, Musick and Lamm (1990) concluded that benefits of preplant irrigation are likely to be greatest when the soil profile is dry and growing season irrigation is reduced. With recent dry conditions in certain areas and diminished well capacities, this creates a situation where preplant irrigation may be beneficial. In a more recent study Stone et al. (2008) used simulation modeling to examine the effectiveness of preseason irrigation. They found the differences in storage efficiency between spring and fall irrigation peaked at approximately 37 percentage points (storage efficiency of approximately 70% for spring and 33% for fall irrigation) when the maximum soil water during the preseason period was at approximately 77% of available soil water.

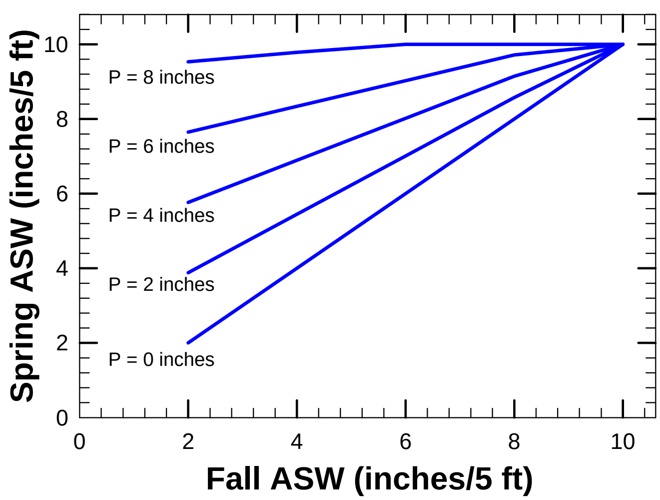

Figure 1. Available soil water in the 5 ft soil profile in the spring (May) as affected by available soil water in the fall (November) and overwinter precipitation (P). Results calculated using an equation from Lamm and Rogers, 1985.

Many of the irrigation systems today in the Central Great Plains no longer have the capacity to apply peak irrigation needs during the summer and must rely on soil water reserves to buffer the crop from water stress. Therefore, this study was conducted to evaluate whether preseason irrigation would be profitable when well capacity is limited and insufficient to fully meet crop requirements.

MATERIALS AND METHODS

A field study was conducted at the KSU-SWREC near Tribune, Kansas from 2006 to 2009. Normal precipitation for the growing season (April through September) is 13.2 in and normal annual precipitation is 17.4 in. The study was a factorial design of preseason irrigation (0 and 3 in), well capacities (0.10, 0.15, and 0.20 in day^{-1} capacity), and seeding rate (22,500, 27,500 and 32,500 seeds a^{-1}). The irrigation treatments were whole plots and the plant populations were subplots. Each treatment combination was replicated four times and applied to the same plot each year. The irrigation treatments were applied with a lateral-move sprinkler with amounts limited to the specified well capacities. Preseason irrigation was applied in early April and in-season irrigations were applied from about mid-June through early September. The in-season irrigations were generally applied weekly except when precipitation was sufficient to meet crop needs. Corn was planted in late April or early May each year. The center two rows of each plot were machine harvested with grain yields adjusted to 15.5% moisture (wet basis). Plant and ear populations were determined by counting plants and ears in the center two rows prior to harvest. Seed weights (oven-dried) were determined on 100-count samples from each plot. Kernels per ear were calculated from seed weight, ear population, and grain yield. Soil water measurements (8 ft depth in 1 ft increments) were taken throughout the growing season using neutron attenuation. All water inputs, precipitation and irrigation, were measured.

Crop water use was calculated by summing soil water depletion (soil water at planting less soil water at harvest) plus in-season irrigation and precipitation. In-season irrigations were 9.6, 12.6, and 19.0 inches in 2006; 7.2, 10.1, 15.6 inches in 2007; 8.2, 11.0, 14.8 inches in 2008; and 8.8, 11.8, 17.9 inches in 2009 for the 0.10, 0.15, and 0.20 in day^{-1} well capacity treatments, respectively. In-season precipitation was 6.9 inches in 2006, 8.1 inches in 2007, 9.4 inches in 2008; and 14.4 inches in 2009. Non-growing season soil water accumulation was the increase in soil water from harvest to the amount at planting the following year. Non-growing season precipitation was 15.0 inches in 2007, 4.2 inches in 2008, and 8.6 inches in 2009 with an average of 9.3 in. Precipitation storage efficiency (without preseason irrigation) was calculated as non-growing season soil water accumulation divided by non-growing season precipitation. Crop water productivity (CWP) was calculated by dividing grain yield (lb a^{-1}) by crop water use (in). Local corn prices ($3.39, 4.80, 3.96, and 3.46 bu^{-1} in 2006, 2007, 2008, and 2009, respectively), crop input costs, and custom rates were used to perform an economic analysis to determine net return to land, management, and irrigation equipment for each treatment.

RESULTS AND DISCUSSION

Preseason irrigation increased grain yields an average of 16 bu a^{-1} (Table 1). Although not significant, the effect was greater at lower well capacities. For example, with a seeding rate of 27,500 seeds a^{-1}, preseason irrigation (3 in) increased grain yield by 21 bu a^{-1} with a well capacity of 0.10 in day^{-1} while only 7 bu a^{-1} with a well capacity of 0.20 in day^{-1}. As expected, grain yields increased with increased well capacity. Grain yields (averaged across preseason irrigation and seeding rate) were 29% greater when well capacity was increased from 0.1 to 0.2 in day^{-1}. Preseason irrigation and increased well capacity increased the number of seeds ear^{-1} but had little impact on seed weight.

The optimum seeding rate varied with irrigation level. With the two lowest well capacities and without preseason irrigation, a seeding rate of 22,500 seeds a^{-1} was generally adequate. However, if preseason irrigation was applied, then a higher seeding rate (27,500 seeds a^{-1}) increased yields. With a well capacity of 0.2 in day^{-1}, a seeding rate of 32,500 seeds a^{-1} provided greater yields with or without preseason irrigation.

Crop water productivity was not significantly affected by well capacity or preseason irrigation (Table 1), although the trend was for greater CWP with increased water supply. Similar to grain yields, the effect of seeding rate varied with irrigation level. With lower irrigation levels, a seeding rate of 27,500 seeds a^{-1} tended to optimize CWP. It was only at the highest well capacity that a higher seeding rate improved CWP.

Crop water use increased with well capacity and preseason irrigation (Table 2). Soil water at harvest increased with increased well capacity, but this caused less soil water to accumulate during the winter. Non-growing season soil water accumulation averaged 2.7 in (without preseason irrigation). Average non-growing season precipitation was 9.3 in giving an average non-growing season precipitation storage efficiency of 29%. Preseason irrigation (about 3 in) increased available soil water at planting by 1.7 in. Seeding rate had minimal effect on soil water at planting or crop water use but increased seeding rate tended to decrease soil water at harvest and increase over-winter water accumulation.

Preseason irrigation was found to be profitable at all irrigation capacities (Table 3). At the two lower well capacities, a seeding rate of 27,500 seeds a^{-1} was generally the most profitable. However, the highest irrigation capacity benefited from a seeding rate of 32,500 seeds a^{-1}.

CONCLUSIONS

Corn grain yields responded positively to preseason irrigation and increases in well capacity. This yield increase generally resulted from increases in kernels ear^{-1}. Preseason irrigation was profitable at all well capacities. Seeding rate should be adjusted for the amount of irrigation water available from both well capacity and preseason irrigation. At well capacities of 0.10 and 0.15 in day^{-1}, a seeding rate of 27,500 seeds a^{-1} was generally more profitable than lower or higher seeding rates. A higher seeding rate (32,500 seeds a^{-1}) increased profitability when well capacity was increased to 0.20 in day^{-1}.

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Table 1. Crop parameters of corn as affected by well capacity, preseason irrigation, and seeding rate, Tribune, Kansas, 2006 - 2009.

Well capacity	Pre-season irrigation	Seed rate	Grain yield	Crop water prod.	Plant pop.	Ear pop.	1000 seed	Kernel
in day^{-1}		10^3 a^{-1}	bu a^{-1}	lb ac-in^{-1}	- 10^3 acre^{-1} -		oz	# head^{-1}
0.10	no	22.5	153	386	22.4	21.5	13.20	476
		27.5	158	397	26.7	24.7	12.75	442
		32.5	155	389	31.2	28.8	12.46	379
	yes	22.5	171	403	21.9	21.5	13.43	531
		27.5	179	416	26.7	25.3	13.15	478
		32.5	183	419	31.5	29.6	12.80	427
0.15	no	22.5	172	389	22.2	21.2	13.24	543
		27.5	173	395	27.0	25.9	12.93	465
		32.5	171	383	31.1	29.2	12.84	406
	yes	22.5	185	405	22.4	21.9	13.36	563
		27.5	197	431	27.0	26.2	13.08	512
		32.5	201	433	31.4	30.2	12.80	466
0.20	no	22.5	200	404	22.3	22.0	13.29	615
		27.5	211	414	27.0	26.8	13.02	544
		32.5	223	440	31.8	31.3	12.74	503
	yes	22.5	204	396	22.1	21.9	13.59	617
		27.5	218	414	27.0	26.8	13.27	551
		32.5	229	436	31.9	31.2	12.74	517
ANOVA (P>F)								
Well Capacity (WC)			0.001	0.411	0.086	0.001	0.687	0.001
Pre-Season			0.002	0.099	0.659	0.107	0.160	0.001
WC*Pre-Season			0.222	0.297	0.452	0.401	0.752	0.138
Seed Rate			0.001	0.001	0.001	0.001	0.001	0.001
Seed Rate*WC			0.001	0.018	0.012	0.001	0.212	0.176
Seed Rate*Pre-Season			0.018	0.126	0.089	0.345	0.186	0.263
Seed Rate*W*Pre-Season			0.402	0.626	0.427	0.373	0.518	0.295
MEANS	Well cap.	0.10	167	402	26.8	25.2	12.97	456
		0.15	183	406	26.9	25.8	13.04	493
		0.20	214	417	27.0	26.6	13.11	558
		$LSD_{0.05}$	11	25	0.2	0.5	0.35	21
	Pre-season	no	180	400	26.9	25.7	12.94	486
		yes	196	417	26.9	26.1	13.14	518
		$LSD_{0.05}$	9	21	0.2	0.4	0.28	17
	Seed rate	22,500	181	397	22.2	21.7	13.35	558
		27,500	189	411	26.9	25.9	13.03	499
		32,500	194	417	31.5	30.1	12.73	450
		$LSD_{0.05}$	3	8	0.2	0.3	0.09	10

Table 2. Available soil water in 8 ft profile, crop water use, and non-growing season water accumulation for corn as affected by well capacity, preseason irrigation, and seeding rate, Tribune, Kansas, 2006 - 2009.

Well capacity	Pre-season irrigation	Seed rate	Available soil water: Planting	Available soil water: Harvest	Water use	Non-growing season accumulation.
in day^{-1}		10^3 a^{-1}	- - in 8 ft. profile^{-1} - -		in	in 8 ft. profile^{-1}
0.10	no	22.5	8.36	5.21	21.28	2.79
		27.5	8.24	4.83	21.55	2.73
		32.5	8.02	4.63	21.52	2.78
	yes	22.5	10.66	5.43	23.36	5.02
		27.5	10.52	4.88	23.78	5.30
		32.5	10.83	4.96	24.00	5.33
0.15	no	22.5	8.78	5.47	24.35	2.71
		27.5	9.17	6.08	24.13	2.56
		32.5	9.06	5.68	24.42	2.98
	yes	22.5	10.51	6.19	25.36	4.05
		27.5	10.46	6.15	25.35	4.77
		32.5	10.71	5.98	25.76	5.05
0.20	no	22.5	10.51	9.07	27.94	2.14
		27.5	9.95	7.86	28.59	3.02
		32.5	10.56	8.53	28.53	2.82
	yes	22.5	13.44	10.82	29.11	3.15
		27.5	13.22	10.13	29.58	3.68
		32.5	12.90	9.85	29.55	3.55
ANOVA (Probability>F)						
Well capacity (WC)			0.010	0.001	0.001	0.001
Pre-season			0.001	0.266	0.001	0.001
WC*Pre-season			0.647	0.587	0.010	0.001
Seed rate			0.779	0.076	0.001	0.002
Seed rate*WC			0.692	0.173	0.059	0.156
Seed rate*Pre-season			0.985	0.820	0.546	0.424
Seed rate*WC*Pre-season			0.389	0.625	0.749	0.303
MEANS	Well capacity	0.10	9.44	4.99	22.58	3.99
		0.15	9.78	5.92	24.89	3.69
		0.20	11.76	9.37	28.88	3.06
		$LSD_{0.05}$	1.49	1.77	0.39	0.38
	Pre- season	no	9.18	6.37	24.70	2.73
		yes	11.47	7.15	26.21	4.43
		$LSD_{0.05}$	1.22	1.44	0.32	0.31
	Seed rate	22.5	10.38	7.03	25.23	3.31
		27.5	10.26	6.65	25.50	3.68
		32.5	10.35	6.61	25.63	3.75
		$LSD_{0.05}$	0.34	0.40	0.18	0.24

Table 3. Net return to land, irrigation equipment, and management from preseason irrigation (0 or 3 in) at three irrigation well capacities and three seeding rates at Tribune, Kansas 2006-2009.

Well capacity	Preseason Irrigation	Seeding rate (10^3 a^{-1})		
		22.5	27.5	32.5
in day^{-1}		Net return, \$ a^{-1} yr^{-1}		
0.10	No	231	238	214
	Yes	285	300	297
0.15	No	290	283	261
	Yes	321	352	357
0.20	No	415	449	485
	Yes	417	458	492

Corn research plots being irrigated with a lateral move sprinkler irrigation system at Kansas State University.